A/63/46

United Nations

Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

Fifty-sixth session
(10-18 July 2008)

General Assembly
Official Records
Sixty-third Session
Supplement No. 46

General Assembly
Official Records
Sixty-third Session
Supplement No. 46

Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

Fifty-sixth session
(10-18 July 2008)

United Nations • New York, 2008

Note

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

ISSN 0255-1373

[11 August 2008]

Contents

Chapter		*Page*
I.	Introduction	1
II.	Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its fifty-sixth session	2
III.	Strategic plan and programme of work of the Committee	4
IV.	Scientific report	6
	A. Sources of radiation exposure	9
	B. Chernobyl accident	24
	C. Effects on non-human biota	28

Appendices

I.	Members of national delegations attending the fiftieth to fifty-sixth sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation, at which the 2008 scientific report was elaborated	30
II.	Scientific staff and consultants cooperating with the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of the 2008 scientific report of the Committee	32

I. Introduction

1. Exposure to radiation has origins such as medical diagnostic and therapeutic procedures; nuclear weapons production and testing; natural background radiation; nuclear electricity generation; accidents such as the one at Chernobyl in 1986; and occupations that entail increased exposure to artificial or naturally occurring sources of radiation.

2. Since the establishment of the United Nations Scientific Committee on the Effects of Atomic Radiation by General Assembly resolution 913 (X) of 3 December 1955, the mandate of the Committee has been to undertake broad reviews of the sources of ionizing radiation and of the effects of that radiation on human health and the environment. In pursuit of its mandate, the Committee thoroughly reviews and evaluates global and regional exposures to radiation; and it evaluates evidence of radiation-induced health effects in exposed groups, including survivors of the atomic bombings in Japan. The Committee also reviews advances in the understanding of the biological mechanisms by which radiation-induced effects on health or on the environment can occur. Those assessments provide the scientific foundation used, inter alia, by the relevant agencies of the United Nations system in formulating international standards for protection of the public and of workers against ionizing radiation;[1] those standards, in turn, are linked to important legal and regulatory instruments.

[1] The international basic safety standards for protection against ionizing radiation and for the safety of radiation sources are currently co-sponsored by the International Labour Organization, the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development and the Pan American Health Organization.

II. Deliberations of the United Nations Scientific Committee on the Effects of Atomic Radiation at its fifty-sixth session

3. The Committee held its fifty-sixth session in Vienna from 10 to 18 July 2008.[2] Norman Gentner (Canada), Wolfgang Weiss (Germany) and Mohamed A. Gomaa (Egypt) served as Chairman, Vice-Chairman and Rapporteur, respectively. The Committee scrutinized and approved for publication five scientific annexes that had last been considered at its fifty-fifth session (21-25 May 2007), as reported to the General Assembly in the report of the Committee on that session.[3] As previously reported,[4] the Committee had originally planned that those documents would be published by 2005.

4. With regard to the report with scientific annexes that it had approved in 2006,[5] the Committee was disappointed that volume I had not been published until July 2008 and that volume II would likely not be published before December 2008, bearing in mind that Member States and some organizations[6] relied on the information contained in that report, to which the Committee members had contributed invaluable expertise. It was observed that the delays were traceable in part to inadequate staffing and to a lack of sufficient, assured and predictable funding.

5. The Committee noted that the General Assembly, in its resolution 62/100 of 17 December 2007, had appealed to the Secretary-General to take appropriate administrative measures so that the secretariat could adequately service the Committee in a predictable and sustainable manner; and had requested the Secretary-General to provide a comprehensive and consolidated report to the Assembly at its sixty-third session, to be prepared in consultation with the Committee as appropriate, addressing the financial and administrative implications of increased Committee membership, staffing of the professional secretariat and methods to ensure sufficient, assured and predictable funding. The secretariat was

---

[2] The fifty-sixth session of the Committee was attended by members of the Committee and by the official contact points of Belarus, the Russian Federation and Ukraine, for matters related to the Chernobyl accident; observers for Belarus, Finland, Pakistan, the Republic of Korea, Spain and Ukraine; and observers for the United Nations Environment Programme (UNEP), WHO, IAEA, the International Agency for Research on Cancer, the European Commission, the International Commission on Radiological Protection, the International Commission on Radiation Units and Measurements, the International Organization for Standardization and the International Union of Radioecology.

[3] *Official Records of the General Assembly, Sixty-second Session, Supplement No. 46* (A/62/46), para. 3.

[4] Ibid., *Fifty-sixth Session, Supplement No. 46* (A/56/46), para. 10.

[5] Ibid., *Sixty-first Session, Supplement No. 46* (A/61/46), para. 2.

[6] At its fifty-first regular session, the IAEA General Conference, in its resolution GC(51)/RES/11, entitled "Measures to strengthen international cooperation in nuclear, radiation and transport safety and waste management", noted that the IAEA Secretariat had commenced revision of the International Basic Safety Standards for Protection against Ionizing Radiation and the Safety of Radiation Sources with the participation of co-sponsors; noted the report of the United Nations Scientific Committee on the Effects of Atomic Radiation on its fifty-fourth session (*Official Records of the General Assembly, Sixty-first Session, Supplement No. 46* (A/61/46)); and urged the IAEA Secretariat to consider carefully and to justify any potential changes to the Basic Safety Standards, ensuring consistency with, inter alia, the Committee's report.

requested to facilitate the inclusion in the Secretary-General's report of the views of the Committee on those matters.

6. The Committee decided to hold its fifty-seventh session in Vienna from 25 to 29 May 2009.

III. Strategic plan and programme of work of the Committee

7. The Committee had developed a strategic plan[7] to provide vision and direction for all its activities during the period 2009-2013, to facilitate result-based programming by the secretariat, to help foster management of sufficient, assured and predictable resources and to improve planning and coordination among the various parties involved.

8. The Committee considered that its strategic objective for the period was to increase awareness and deepen understanding among authorities, the scientific community and civil society with regard to levels of ionizing radiation and the related health and environmental effects as a sound basis for informed decision-making on radiation-related issues.

9. It was established that the thematic priorities for the period would be medical exposures of patients, radiation levels and effects of energy production, exposure to natural sources of radiation and improved understanding of the effects from low-dose-rate radiation exposure.

10. Several strategic shifts were envisaged in order to better meet the needs of Member States, including: (a) streamlining the Committee's scientific evaluation process by preparing short yet wide-ranging summary reports every 4-5 years on the levels and effects of radiation exposure and preparing special reports that respond to emerging issues as the need arises; and establishing standing expert groups to maintain surveillance on emerging issues and networks of centres of excellence to help implement the strategic plan; (b) enhancing mechanisms for data collection, analysis and dissemination; (c) improving result-based planning, including improving coordination with other stakeholders to develop areas of synergy and avoid inconsistencies; and (d) raising awareness and improving outreach by enhancing the website of the Committee and disseminating findings in readily understandable formats to decision makers and the public.

11. It was assumed that, in order to implement the strategic plan, intersessional work by the Committee would increase and action would have to be taken to address both the concern of the Committee that reliance on a single Professional-level post in its secretariat had left the Committee seriously vulnerable and had hampered the efficient implementation of its approved programme of work, and methods to ensure sufficient, assured and predictable funding, as requested in General Assembly resolution 62/100.

12. For its future programme of work, the Committee decided to initiate work immediately on assessments of levels of radiation from energy production and the effects on human health and the environment; uncertainty in radiation risk estimation; attributability of health effects due to radiation exposure (in response to paragraph 6 of General Assembly resolution 62/100); updating its methodology for estimating exposures due to discharges from nuclear installations; a summary of radiation effects; and improving data collection, analysis and dissemination. Depending on the availability of resources, other work might be undertaken on the biological effects of key internal emitters, medical exposures of patients, enhanced exposures to natural sources of radiation due to human activities, public information

[7] Available on request from the Secretary of the Committee.

and development of a knowledge base on radiation levels and effects. The Committee authorized the secretariat to take appropriate action to implement the strategic plan and future programme of work.

IV. Scientific report

13. The scientific report and its annexes were elaborated from the fiftieth to the fifty-sixth sessions of the Committee on the basis of documents submitted by the secretariat. Serving as Chairman, Vice-Chairman and Rapporteur at those sessions were:

Session	*Chairman*	*Vice-Chairman*	*Rapporteur*
Fiftieth	J. Lipsztein (Brazil)	Y. Sasaki (Japan)	R. Chatterjee (Canada)
Fifty-first	J. Lipsztein (Brazil)	Y. Sasaki (Japan)	R. Chatterjee (Canada)
Fifty-second	Y. Sasaki (Japan)	R. Chatterjee (Canada)	P. Burns (Australia)
Fifty-third	Y. Sasaki (Japan)	P. Burns (Australia)	N. Gentner (Canada)
Fifty-fourth	P. Burns (Australia)	N. Gentner (Canada)	C. Streffer (Germany)
Fifty-fifth	P. Burns (Australia)	N. Gentner (Canada)	W. Weiss (Germany)
Fifty-sixth	N. Gentner (Canada)	W. Weiss (Germany)	M. Gomaa (Egypt)

14. The names of the members of national delegations who attended those sessions are listed in appendix I. The Committee wishes to acknowledge the contribution of the representatives of specialized agencies of the United Nations system and other organizations to the discussion. The Committee also wishes to recognize a small group of consultants who helped prepare the material (see appendix II). They were responsible for the preliminary assessment of the relevant technical information, on which rested the final deliberations of the Committee.

15. In conducting its work, the Committee applied scientific judgement to the material it reviewed and took care to assume an independent and neutral position in reaching its conclusions. Following established practice, the findings are presented in the present report. The supporting scientific annexes are aimed at the scientific community and will be issued separately as a United Nations sales publication.

Overview

16. For as long as they have been on the planet, humans have been exposed to ionizing radiation from natural sources, although exposure may be modified by human activity. In addition, new, artificial sources of exposure have developed over the past century or so. The Committee last made estimates of radiation exposure levels and trends in its 2000 report.[8] The present report updates and extends those estimates; table 1 summarizes the updated values for average annual doses and ranges of exposure from all sources.[9]

[8] *Official Records of the General Assembly, Fifty-fifth Session, Supplement No. 46* (A/55/46).

[9] See paragraph 26 below for a discussion of the concept of radiation dose.

Table 1
Annual average doses and ranges of individual doses of ionizing radiation by source
(Millisieverts[a])

Source or mode	*Annual average dose (worldwide)*	*Typical range of individual doses*	*Comments*
Natural sources of exposure			
Inhalation (radon gas)	1.26	0.2-10	The dose is much higher in some dwellings.
External terrestrial	0.48	0.3-1	The dose is higher in some locations.
Ingestion	0.29	0.2-1	
Cosmic radiation	0.39	0.3-1	The dose increases with altitude.
Total natural	**2.4**	**1-13**	**Sizeable population groups receive 10-20 millisieverts (mSv).**
Artificial sources of exposure			
Medical diagnosis (not therapy)	0.6	0-several tens	The averages for different levels of health care range from 0.03 to 2.0 mSv; averages for some countries are higher than that due to natural sources; individual doses depend on specific examinations.
Atmospheric nuclear testing	0.005	Some higher doses around test sites still occur.	The average has fallen from a peak of 0.11 mSv in 1963.
Occupational exposure	0.005	~0-20	The average dose to all workers is 0.7 mSv. Most of the average dose and most high exposures are due to natural radiation (specifically radon in mines).
Chernobyl accident	0.002[b]	In 1986, the average dose to more than 300,000 recovery workers was nearly 150 mSv; and more than 350,000 other individuals received doses greater than 10 mSv.	The average in the northern hemisphere has decreased from a maximum of 0.04 mSv in 1986. Thyroid doses were much higher.
Nuclear fuel cycle (public exposure)	0.0002[b]	Doses are up to 0.02 mSv for critical groups at 1 km from some nuclear reactor sites.	
Total artificial	**0.6**	**From essentially zero to several tens**	**Individual doses depend primarily on medical treatment, occupational exposure and proximity to test or accident sites.**

[a] Unit of measurement of effective dose.

[b] Globally dispersed radionuclides. The value for the nuclear fuel cycle represents the maximum per caput annual dose to the public in the future, assuming the practice continues for 100 years, and derives mainly from globally dispersed, long-lived radionuclides released during reprocessing of nuclear fuel and nuclear power plant operation.

17. The main natural sources of exposure are cosmic radiation and natural radionuclides found in the soil and in rocks. Cosmic radiation is significantly higher at the cruising altitudes of jet aircraft than on the Earth's surface. External exposure rates due to natural radionuclides vary considerably from place to place, and can range up to 100 times the average. An important radionuclide is radon, a gas that is formed during the decay of natural uranium in the soil and that seeps into homes. Exposures due to inhalation of radon by people living and working indoors vary dramatically depending on the local geology, building construction and household lifestyles; this mode of exposure accounts for about half of the average human exposure to natural sources.

18. The Committee evaluated the additional radiation exposures introduced by military and peaceful activities. Nuclear test explosions in the atmosphere had been conducted at a number of sites, mostly in the northern hemisphere, the most active testing being in the periods 1952-1958 and 1961-1962. The radioactive fallout from those tests represents a source of continuing exposure even today, albeit at very low levels. There is concern regarding the return of residents to nuclear test areas, because radioactive residue levels are considerable at some sites. People living near sites where nuclear materials and weapons had been produced are also exposed to radiation. Military use of depleted uranium, especially in armour-piercing munitions, has raised concerns about residual contamination; however, radiation exposures are generally negligible.

19. With regard to the peaceful uses of radiation, medical exposures were by far the dominant form. Medical exposure is almost always voluntary and provides a direct benefit to the exposed individual. Irrespective of the level of health care in a country, the medical uses of radiation continue to increase as techniques develop and become more widely disseminated; about 3.6 billion radiological examinations are conducted worldwide every year. In countries with high levels of health care, exposure from medical uses is on average now equal to about 80 per cent of that from natural sources.

20. The generation of electrical energy by nuclear power plants has grown steadily since 1956. The nuclear fuel cycle includes the mining and milling of uranium ore; fuel fabrication; production of energy in the nuclear reactor; storage or reprocessing of irradiated fuel; and the storage and disposal of radioactive wastes. The doses to which the public is exposed vary widely from one type of installation to another, but they are generally small and they decrease markedly the further the distance from the facility. Doses from nuclear power reactors to local and regional populations decrease over time because of lower discharge levels.

21. In the area of occupational exposure, attention had traditionally focused on artificial sources of radiation; however, it is now recognized that a very large number of workers are exposed to natural sources. Occupational exposures at commercial nuclear power plants have been falling steadily over the past three decades, albeit with significant differences between reactor types. Estimates for exposure related to the nuclear fuel cycle are generally more robust and comprehensive than for other uses of radiation. By contrast, the monitoring and reporting of occupational exposures in the medical and industrial sectors is less comprehensive. While the average dose to workers in all occupational groups has dropped substantially over the past two decades, occupational exposures from natural radiation sources have changed little.

22. A small number of accidents have occurred in association with the nuclear fuel cycle and have attracted widespread publicity. However, more than 100 accidents have occurred with industrial and medical sources, especially in settings termed "orphaned" (i.e. outside regulatory control), and those accidents have caused injury to workers and the public. Accidents can also occur during medical uses of radiation, usually involving human or machine error in radiotherapy. While it is known that accidents involving orphan sources and medical uses of radiation have become more frequent, the current figures are likely to be underestimates, and possibly significantly so, because of underreporting.

23. The accident at the Chernobyl nuclear power plant in 1986 was the most severe such accident in the history of civilian nuclear power. Two workers died in the immediate aftermath, and 134 plant staff and emergency personnel suffered acute radiation syndrome, which proved fatal for 28 of them. Several hundred thousand workers were subsequently involved in recovery operations. Among the persons exposed to the highest radiation doses in 1986 and 1987, there are some reports of increased incidence of leukaemia and of cataracts; there is no other consistent evidence to date of other radiation-related health effects. The radioactive cloud created by the accident deposited substantial amounts of radioactive material over large areas of the former Soviet Union and other parts of Europe, contaminating land, water and biota and causing particularly serious social and economic disruption to large segments of the population in the countries known today as Belarus, the Russian Federation and Ukraine. Among the people who were children or adolescents in 1986 in affected areas of the former Soviet Union, more than 6,000 cases of thyroid cancer have been reported (to date only a small number of them fatal), of which a substantial portion could be attributed to drinking milk contaminated with the short-lived radionuclide iodine-131. In the longer term, the general population too was exposed to radiation (of the low-level chronic type) but there has been no consistent evidence yet of any other radiation-related health effects in the general population.

24. In its 1996 scientific report, the Committee evaluated the rates of exposure below which effects on populations of species other than humans were unlikely. The Committee has since reviewed the approaches to evaluating radiation doses to species other than humans, together with new scientific information on the radiobiological effects on plants and animals (in particular information from the continuing follow-up of the environmental consequences of the Chernobyl accident). That review has revealed no evidence to support changing the conclusions of the 1996 report according to which no effects are expected at chronic dose rates below 0.1 milligrays per hour or at acute doses below 1 gray to the most highly exposed individuals in the exposed population.

A. Sources of radiation exposure

25. All matter is made up of atoms. Some atoms are naturally stable, others are unstable. Radioactivity is a natural phenomenon that occurs when an atom with an unstable nucleus spontaneously transforms, releasing energy in the form of ionizing radiation. These unstable elements are known as radionuclides and they are radioactive. The released radiation may take the form of particles (including electrons, neutrons and alpha particles) or of electromagnetic gamma radiation or

X-rays, all with different amounts of energy. Radiation can also be generated artificially by machines.

26. When ionizing radiation passes through matter, including living tissue, it deposits energy that ultimately produces ionization and excitation in the matter. The amount of energy deposited divided by the mass of tissue exposed is called the absorbed dose and is usually measured in units known as milligrays. The biological damage caused by radiation is related to the amount of energy deposited. However, to estimate the potential biological effect, allowance is made for the fact that different kinds of radiation have different biological effects for the same amount of energy deposited and the fact that tissues also react differently. A weighted quantity called the effective dose is used in radiation protection, and is the most commonly used indicator of the potential biological effects associated with exposure to ionizing radiation in humans. The effective dose (here simply "dose") is usually expressed in millisieverts (mSv). The total exposure of a group of people to radiation is called the collective dose and is expressed in man-sieverts (man Sv). As a reference for subsequent comparisons, the annual global average per caput dose from natural background radiation is 2.4 mSv, while the corresponding annual collective dose to the global population from natural background radiation is about 16 million man Sv.

1. Natural sources

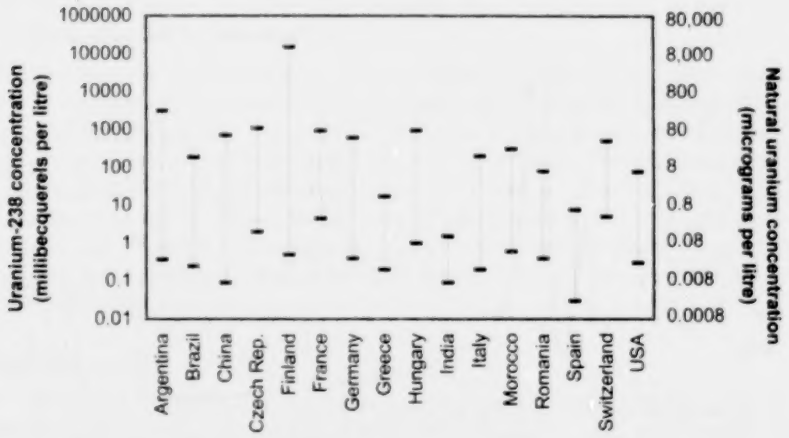
27. For most individuals, exposure to natural background radiation is the largest component of their total radiation exposure. Although the sources of radiation are natural, exposures are affected by human activity, of which the simplest example is living in a house. Building materials provide shielding against radiation from the ground but may themselves contain radionuclides that increase exposure. In addition, buildings may trap radon gas and thus increase exposures vis-à-vis those occurring in the open air.

28. Cosmic radiation (i.e. radiation originating in outer space) is significantly attenuated by the Earth's atmosphere. At sea level it contributes about 15 per cent of the total dose from natural radiation sources; however, at higher altitudes and especially in outer space, it is the dominant radiation source. At cruising altitudes of commercial aircraft, the average dose rates are 0.003-0.008 mSv per hour, some two orders of magnitude higher than at sea level.

29. Everything in and on the Earth contains radionuclides. The so-called primordial radionuclides found in the ground (potassium-40, uranium-238 and thorium-232), together with the radionuclides into which they decay, emit radiation. Estimates of external exposure[10] vary considerably from one location to another. Some specific locations have such high concentrations of these radionuclides that the dose rates may be 100 times the global average value. These radionuclides and some formed by the interaction of cosmic rays with the Earth's atmosphere are also present in food and drink and so become incorporated into the body. Environmental concentrations of natural radionuclides are highly variable (see figure I). Most of the dose from such internal exposure[10] is due to potassium-40.

[10] External exposure is exposure to radiation that originates from outside the body, whereas internal exposure is exposure to radiation that originates from radioactive material inside the body.

Figure I
Variability of natural uranium concentrations observed in drinking water



Note: The vertical lines express the range of values observed in the country. Note that the scales on the vertical axes increase by factors of 10.

30. One radionuclide produced from the uranium-238 decay series is radon-222 (or simply "radon"). This gas is a normal constituent of soil gas and seeps into buildings. When radon is inhaled, some of its short-lived decay products are retained in the lungs and irradiate cells in the respiratory tract. Radon levels vary dramatically depending on the underlying local geology and other factors such as the permeability of the soil, construction of the building, climate and household lifestyles. Very extensive measurement programmes have been conducted and have formed the basis for implementing measures to reduce indoor radon concentrations. Radon accounts for about half of the average exposure to natural sources of radiation.

31. The estimates of annual average and individual doses of ionizing radiation from exposure to all natural radiation sources are shown above in table 1.

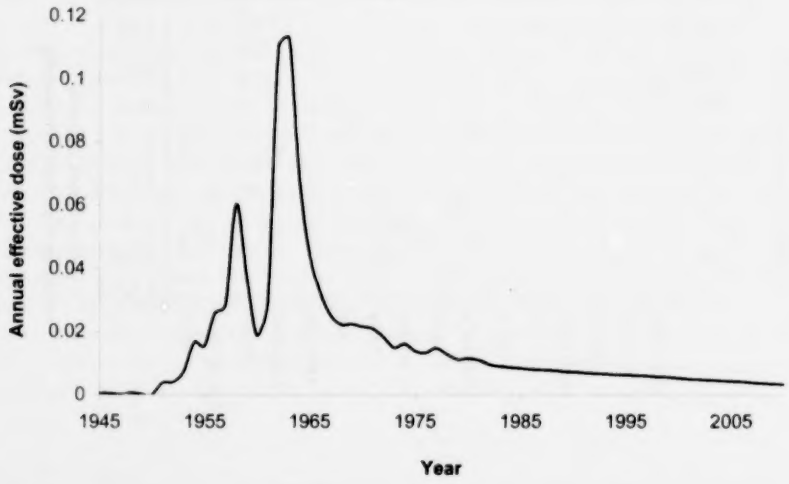
2. Artificial sources

(a) Exposures from military activities

32. Nuclear test explosions in the atmosphere were conducted at a number of sites, mostly in the northern hemisphere, between 1945 and 1980, the most active testing being in the periods 1952-1958 and 1961-1962. In all, 502 tests were conducted, with a total yield of 434 megatons of trinitrotoluene (TNT) equivalent. The estimated annual per caput effective dose of ionizing radiation due to global fallout from atmospheric nuclear weapons testing was highest in 1963, at 0.11 mSv, and subsequently fell to its present level of about 0.005 mSv (see figure II). This source of exposure will decline only very slowly in the future as most of it is now due to the long-lived radionuclide carbon-14.

Figure II

Estimated annual per caput effective dose of ionizing radiation worldwide from atomic bomb tests, 1945-2005



33. People living near test sites were exposed also to local fallout. Because the sites and the characteristics of the tests differed substantially, doses can only be estimated separately after very detailed studies at each site. Many of those studies were carried out in the late 1990s and the early years of the present decade and are still continuing. It is clear that some people living near the sites at the time of testing received very large doses. Presently there is concern regarding the return to use of nuclear test areas, since radioactive residue in some environments may be considerable.

34. From 1962 to 1990, following the signature of the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water,[11] typically up to 50 or more explosions were conducted underground annually; a few tests were also conducted after that. Most underground tests had a much lower yield than atmospheric tests, and any radioactive debris was usually contained unless gases were vented or leaked into the atmosphere. The tests generated a very large quantity of radioactive residue, but that residue is not expected to expose the public to radiation because it is located deep underground and essentially is fused with the host rock.

35. In addition to the weapons tests themselves, the installations where nuclear materials were produced and nuclear weapons were manufactured were another source of radionuclide releases leading to radiation exposure of local populations.

36. A by-product of uranium enrichment is depleted uranium, which is less radioactive than natural uranium. Its chemical toxicity is its most hazardous

[11] United Nations, *Treaty Series*, vol. 480, No. 6964.

property. Except for a few specific scenarios (such as long-term handling), radiation exposures should be negligible.

(b) Exposures from peaceful activities

(i) Radiation exposures of patients

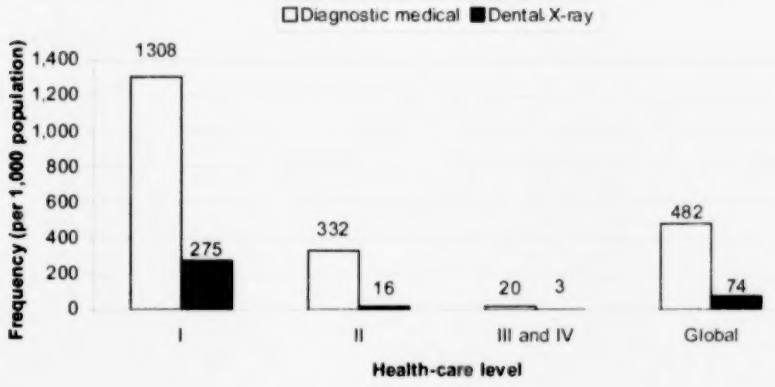
37. The exposure of patients to ionizing radiation relates to diagnostic radiology, nuclear medicine and radiotherapy. The Committee conducted a survey of medical exposures for the period 1997-2007. There are some limitations on the survey data, with the majority of the responses being received from relatively more developed countries. Explicit comparison of doses resulting from medical exposures with those from other sources is inappropriate, as patients receive a direct benefit from their exposure and, moreover, they may be sick or older than the general population. In fact, increasing medical exposure is likely associated with increased health benefits to the population.

Diagnostic medical exposures

38. Since the previous survey (covering the period 1991-1996), the total number of diagnostic medical examinations (both medical and dental) is estimated to have risen from 2.4 billion to 3.6 billion – an increase of approximately 50 per cent. As in previous reports of the Committee, data are grouped according to a country's health-care level (I, II, III or IV – I being the highest, IV the lowest – based on the number of physicians per population). Figure III shows, for the period 1997-2007, the annual frequency of medical X-ray examinations by health-care level. As can be seen from the figure, such examinations were over 65 times more frequent in level I countries (which account for 24 per cent of the global population) than in level III and IV countries (which account for 27 per cent of the global population). The wide imbalance in health-care provision is also reflected in the availability of X-ray equipment and of physicians.

Figure III

Average annual frequency of diagnostic medical and dental X-ray examinations, by health-care level, 1997-2007



39. Table 2 shows the trend in the use of diagnostic radiology and the associated exposures.

Table 2
Trend in radiation exposure from diagnostic radiology

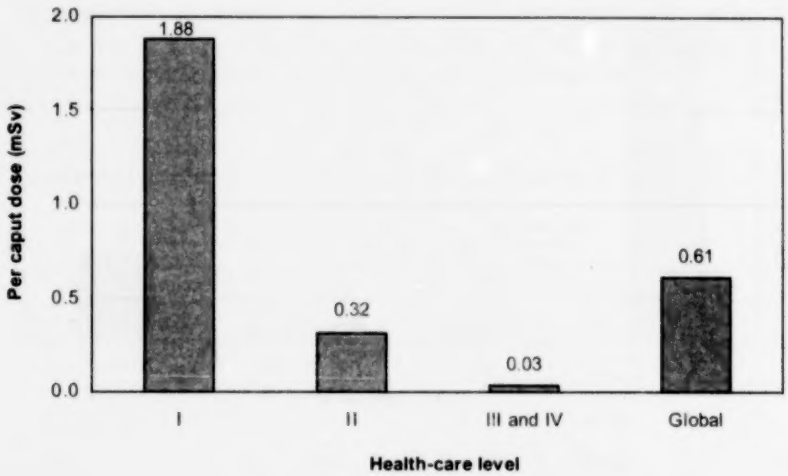
Year of Committee report in which survey data were analysed	*Number of examinations (millions)*	*Collective effective dose (man Sv)*	*Annual per caput dose (mSv)*
1988	1 380	1 800 000	0.35
1993	1 600	1 600 000	0.3
2000	1 910	2 300 000	0.4
2008	3 100	4 000 000	0.6

40. As part of that trend, new, high-dose X-ray technology (particularly computed tomography scanning) is causing extremely rapid growth in the annual number of procedures performed in many countries and, by extension, a marked increase in collective doses. For several countries, this has resulted, for the first time in history, in a situation where the annual collective and per caput doses of ionizing radiation due to diagnostic radiology have exceeded those from the previously largest source (natural background radiation).

41. Since the last survey analysed by the Committee, the total collective effective dose from medical diagnostic examinations is estimated to have increased by 1.7 million man Sv, rising from about 2.3 million to about 4 million man Sv, an increase of approximately 70 per cent. Figure IV shows, for the period 1997-2007, the annual average per caput effective dose of radiation by health-care level and for the global population due to diagnostic medical and dental X-ray examinations.

Figure IV

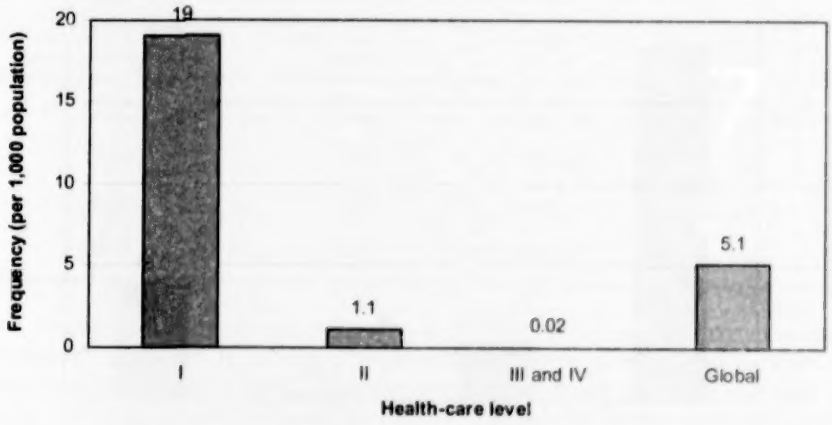
Annual average per caput effective dose of ionizing radiation due to diagnostic medical and dental X-ray examinations, by health-care level, 1997-2007



Nuclear medicine

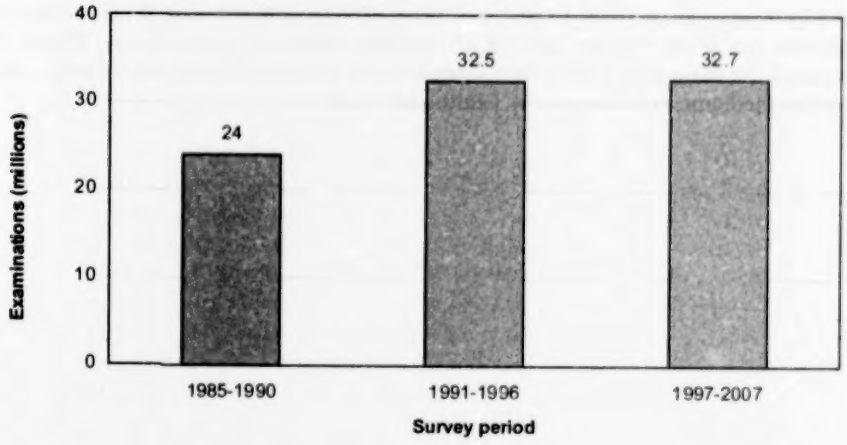
42. An estimated 32.7 million diagnostic nuclear medicine examinations are presently performed annually worldwide, which represents an increase of 0.2 million examinations per year or under 1 per cent since the 1991-1996 survey. Over that same period, the collective effective dose due to nuclear medicine examinations rose from 150,000 to 202,000 man Sv, representing an increase of 52,000 man Sv or about 35 per cent. People living in health-care level I countries account for about 90 per cent of all nuclear medicine examinations. Figure V presents, for the period 1997-2007, a summary of the annual frequency of diagnostic nuclear medicine examinations by health-care level.

Figure V
Annual frequency of diagnostic nuclear medicine examinations, by health-care level, 1997-2007



43. The estimated number of diagnostic nuclear medicine examinations conducted annually has grown over the past three survey periods (1985-1990, 1991-1996 and 1997-2007), as shown in figure VI.

Figure VI
Estimated number of diagnostic nuclear medicine examinations conducted annually, 1985-1990, 1991-1996 and 1997-2007



Radiation therapy

44. Estimated annual data on the most common types of radiotherapy treatment during the period 1997-2007 are shown for each health-care level in table 3. As can be seen, the level I countries accounted for about 70 per cent of all radiotherapy treatments. An estimated 5.1 million courses of radiotherapy treatment were administered annually between 1997 and 2007, up from an estimated 4.3 million in 1988. About 4.7 million of those treatments involved teletherapy and 0.4 million brachytherapy.

Table 3
Estimated annual data on radiotherapy treatments[a] worldwide, 1997-2007

		Teletherapy		*Brachytherapy*[b]		*All radiotherapy treatments*	
Health-care level	*Population (millions)*	*Treatments administered each year (millions)*	*Treatments administered per 1,000 population*	*Treatments administered each year (millions)*	*Treatments administered per 1,000 population*	*Treatments administered each year (millions)*	*Treatments administered per 1,000 population*
I	1 540	3.5	2.2	0.18	0.12	3.6	2.4
II	3 153	1.2	0.4	0.20	0.06	1.4	0.4
III	1 009	0.06	0.06	(<0.05)[c]	(<0.01)[c]	0.1	0.06
IV	744	(0.03)[c]	(<0.01)[c]	(<0.01)[c]	(<0.005)[c]	(0.03)[c]	(0.01)[c]
World[d]	6 446	4.7	0.73	0.4	0.07	5.1	0.8

Source: Committee survey on medical radiation usage and exposures, 1997-2007.

[a] Complete courses of treatment.

[b] Excluding treatments with radiopharmaceuticals.

[c] Assumed value in the absence of data.

[d] Global data include several countries not represented by levels I-IV.

Summary

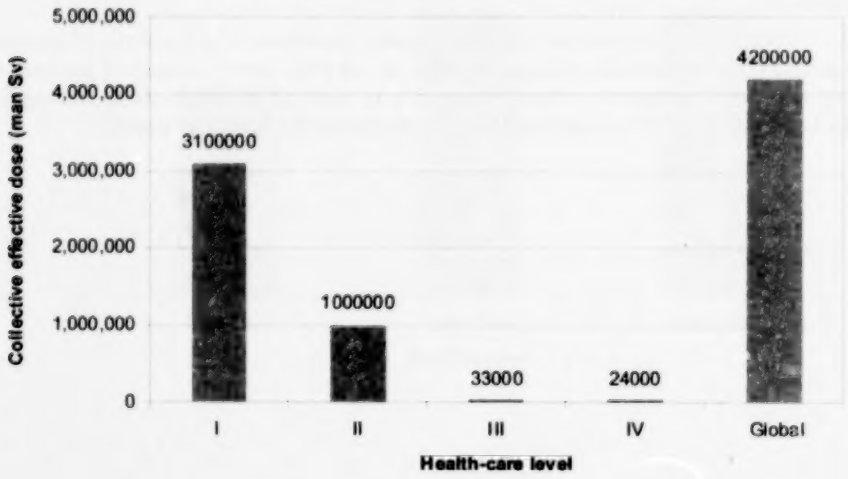
45. Table 4 summarizes the estimated annual collective effective dose of ionizing radiation due to medical exposures for the period 1997-2007. Almost 75 per cent of the worldwide collective effective dose due to medical exposures is accounted for by health-care level I countries (those that are relatively more developed).

Table 4
Estimated annual collective effective dose of ionizing radiation due to medical exposures, 1997-2007
(Totals may not add precisely because of rounding.)

		Source of exposure			
Health-care level	*Population (millions)*	*Diagnostic medical examinations (man Sv)*	*Dental X-ray examinations (man Sv)*	*Nuclear medicine examinations (man Sv)*	*Total (man Sv)*
I	1 540	2 900 000	9 900	186 000	3 100 000
II	3 153	1 000 000	1 300	16 000	1 000 000
III	1 009	33 000	51	82	33 000
IV	744	24 000	38	..	24 000
World	6 446	4 000 000	11 000	202 000	4 200 000

46. Medical exposure remains by far the largest artificial source of exposure to ionizing radiation and continues to grow at a remarkable rate. Medical exposures account for 98 per cent of the contribution from all artificial sources and are now the second largest contributor to the population dose worldwide, representing approximately 20 per cent of the total. About 3.6 billion medical radiation procedures were performed annually during the survey period, compared with 2.5 billion in the previous survey period; that is an increase of 1.1 billion procedures, or over 40 per cent, in the last decade. The total annual collective effective dose due to medical exposures (excluding radiotherapy) stood at approximately 4.2 million man Sv, an increase of 1.7 million man Sv (or just over 65 per cent) over the previous period. The distribution of medical procedures and of doses is markedly uneven among country groups (see figure VII).

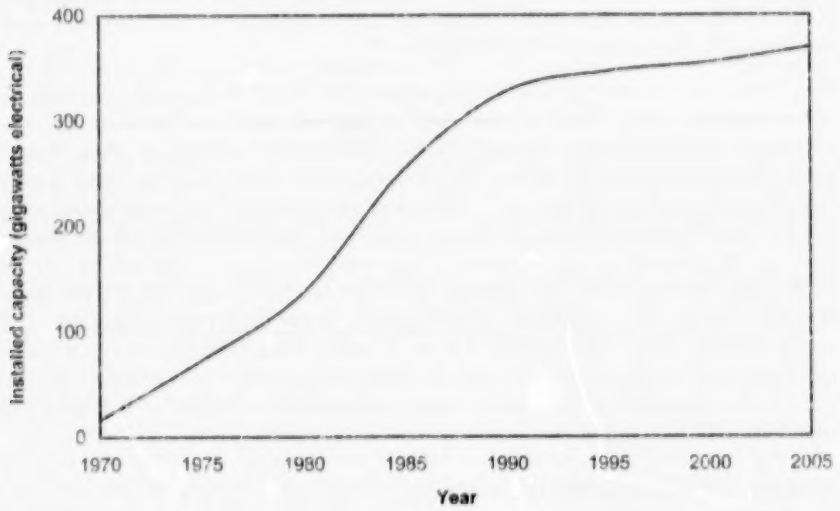
Figure VII
Total annual collective effective dose of radiation due to medical exposures (excluding radiotherapy)



(ii) Radiation exposures of the general public

47. The generation of electrical energy by nuclear power plants has grown steadily since the industry began in 1956. Despite the increase in the decommissioning of older reactors, electrical energy production from nuclear sources continues to grow (see figure VIII). The nuclear fuel cycle has the following stages: mining and milling of uranium ore and its conversion to nuclear fuel; fabrication of fuel elements; production of energy in a nuclear power plant; storage or reprocessing of irradiated fuel; transport between the various stages; and the storage and disposal of radioactive wastes. The doses of ionizing radiation to exposed individuals vary widely from one type of facility to another, between different locations and over time.

Figure VIII
Installed nuclear electricity-generating capacity worldwide, 1970-2005



48. Uranium mining and milling produces substantial quantities of residues in the form of tailings. Until 2003, the total world production of uranium was about 2 million tons while the resultant tailings totalled over 2 billion tons. Current tailings piles are well maintained, but many old, abandoned sites exist and only a few have been remediated. The Committee estimates the current annual collective dose of ionizing radiation to local and regional population groups around mine and mill sites and tailing piles at about 50-60 man Sv, similar to its previous estimates.

49. Most power reactors are of the light-water moderated and cooled type, although other designs are used in some countries. The average annual collective dose of ionizing radiation to local and regional population groups (combined) due to environmental releases from reactors is now estimated to be 75 man Sv. This is lower than previous estimates.

50. In the nuclear fuel cycle, spent fuel is reprocessed to recover uranium and plutonium for reuse in reactors. Most spent fuel is retained in interim storage but about one third of that so far produced has been reprocessed. The estimate of the annual collective dose of ionizing radiation due to reprocessing is still in the range of 20-30 man Sv.

51. The low-level and some of the intermediate-level waste from fuel cycle operations is currently disposed of in near-surface facilities, although waste was sometimes dumped at sea in the past. Both the high-level waste from reprocessing and the spent fuel (if not reprocessed) are stored but will eventually need to be disposed of. The public is expected to be exposed to radiation from disposed waste only in the distant future, if at all, so assessment of the radiological impact has to rely on mathematical modelling. Overall, an annual collective dose of about 200 man Sv is estimated for all operations related to electrical energy production. The dominant component of those operations is mining. The annual per caput dose to representative local and regional populations around nuclear power plants is less than 0.0001 mSv (about equivalent to the dose received from cosmic radiation in a few minutes of air travel).

52. There are several types of facility around the world that, while unrelated to the use of nuclear energy, may all the same expose the public to radiation because of enhanced concentrations of naturally occurring radionuclides in their industrial products, by-products and waste. The most important such facilities involve mining and minerals processing. Besides these, naturally occurring radioactive material can expose people to ionizing radiation as a result of various normal human practices, such as the agricultural use of sludge from water treatment or the use of residue as landfill or building material. Although doses to the public are low, on the order of less than a few thousandths of a millisievert, some especially vulnerable groups could receive doses approaching 1 mSv. A major effort is under way, at both the national and international levels, to assess exposure to naturally occurring radioactive material and to develop strategies to address situations that give rise to increased radiation exposure.

(iii) Radiation exposures of workers

53. Until the 1990s, attention in the area of occupational exposure – apart from the practices related to the nuclear fuel cycle – focused on artificial sources of radiation. Now, however, it is realized that a very large number of workers are exposed occupationally to natural sources of radiation as well, and the current estimate of the resulting collective dose is about three times that indicated in the Committee's 2000 report. The total number of workers exposed to ionizing radiation is currently estimated to be about 22.8 million, of whom about 13 million are exposed to natural sources of radiation and about 9.8 million to artificial sources. Medical workers comprise the largest proportion (75 per cent) of workers exposed to artificial sources of radiation.

54. Radiation exposure of workers involved in military activities occurs during the production and testing of weapons, the operation of reactors for propulsion of naval vessels and other uses similar to those in the civilian sector. The Committee estimates that the worldwide average annual collective dose of ionizing radiation from such sources was about 50-150 man Sv and the average annual worker dose

was about 0.1-0.2 mSv. However, there is a large degree of uncertainty in this estimate.

55. The extraction and processing of radioactive ores that may contain significant levels of natural radionuclides is a widespread activity. The mining sector accounts for the vast majority of occupationally exposed workers, and radon is the main source of radiation exposure in underground mines of all types. Table 5 summarizes the exposure to radon in the workplace.

Table 5
Exposure to radon in the workplace

Workplace	*Number of workers (millions)*	*Collective dose (man Sv)*	*Average effective dose (mSv)*
Coal mines	6.9	16 560	2.4
Other mines[a]	4.6	13 800	3.0
Other workplaces	1.25	6 000	4.8
		Weighted average	**2.9**

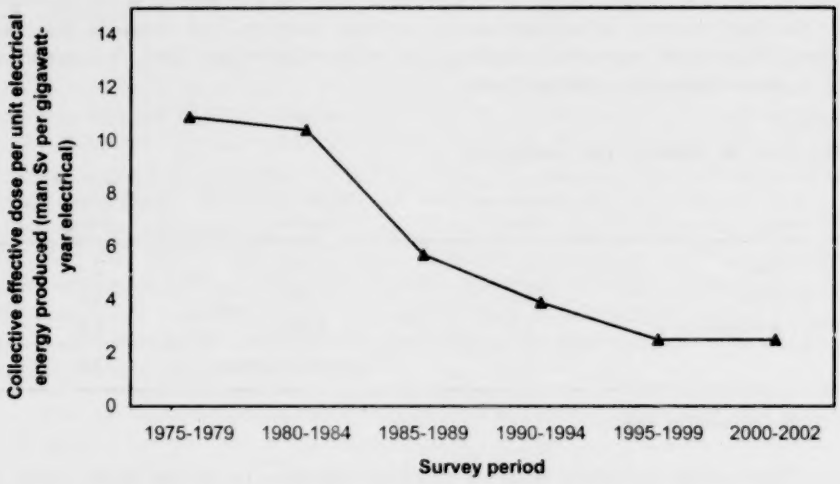
[a] Excluding uranium mines.

56. The annual collective dose of ionizing radiation to airline flight crews is about 900 man Sv. The estimated annual average effective dose is 2-3 mSv. Dose measurements have aiso been made available for a number of space missions. The reported doses for short space missions were in the range of 1.9-27 mSv.

57. The annual collective dose of ionizing radiation to workers involved in the nuclear fuel cycle is estimated to be about 800 man Sv. For the fuel cycle overall, the average annual effective dose is about 1.0 mSv. The average annual dose to monitored workers in the nuclear fuel cycle has gradually declined since 1975, from 4.4 mSv to 1.0 mSv at present. Much of this decline is because of the significant reduction in uranium mining coupled with more advanced mining techniques; concurrently, the total occupational exposure at commercial nuclear power plants divided by the energy produced has also fallen steadily over the past three decades (see figure IX).

Figure IX

Annual occupational collective dose of ionizing radiation at reactors, normalized to unit electrical energy produced, 1975-2002



58. Between 1975 and 1989 the annual collective effective dose averaged over five-year periods for all operations in the nuclear fuel cycle varied little from the average value of 2,500 man Sv despite the three- to four-fold increase in electrical energy generated by nuclear means. The energy generated has continued to increase, but the average annual collective effective dose has fallen by almost half, from 1,400 man Sv in the period 1990-1994 to 800 man Sv in the period 2000-2002.

59. The annual collective dose to workers involved in the medical use of radiation is estimated to be about 3,540 man Sv; the average annual effective dose is about 0.5 mSv. The average annual dose to monitored workers involved in medical uses of radiation increased by a factor of 1.7 from 1994 to 2002. However, workers involved in interventional procedures have high effective doses; and extremity doses can reach the regulatory limits. As the number of interventional procedures has increased significantly, the number of workers involved in the medical use of radiation increased by a factor of seven in the period from 1975 to 2002, and the estimated number was about 7.4 million for 2002.

60. The annual collective dose to workers involved in industrial uses of radiation is estimated to be about 289 man Sv, and the average annual effective dose is about 0.3 mSv. This represents a decrease from the level of 1.6 mSv in 1975. The number of workers involved in industrial uses of radiation increased by a factor of 1.6 in the period from 1975 to 2002; the estimated number was about 0.9 million for 2002.

61. The trends in average annual occupational effective doses of ionizing radiation are shown in table 6 for the periods 1980-1984, 1990-1994 and 2000-2002. A decrease in the average effective dose can be seen for all categories of exposure to artificial sources; the sharp decrease in dose for the nuclear fuel cycle was due mainly to changes in uranium mining. However, the overall weighted average

effective dose increased because of the increased exposure to natural sources of radiation.

Table 6
Trends in average annual occupational effective doses of ionizing radiation, 1980-1984, 1990-1994 and 2000-2002
(Millisieverts)

Source of exposure	*1980-1984*	*1990-1994*	*2000-2002*
Natural sources	..	1.8	2.9
Military activities	0.7	0.2	0.1
Nuclear fuel cycle	3.7	1.8	1.0
Medical uses	0.6	0.3	0.5
Industrial uses	1.4	0.5	0.3
Miscellaneous	0.3	0.1	0.1
Weighted average	**1.3**	**0.8**	**1.8**

(c) Exposures in accidents

62. Early acute effects of radiation exposure occur only as the result of accidents (or malicious acts). Some serious accidents have led to significant population exposures owing to dispersion of radioactive material in the environment. Radiation exposures from accidents have been discussed in several past reports of the Committee, including specific evaluations of the Chernobyl accident. The Committee has categorized and summarized reported radiation accidents that resulted in early acute health effects, deaths or major environmental contamination over the past 60 years.

63. Accidents associated with the nuclear fuel cycle included a small number of serious accidents that received extensive publicity and whose consequences were reported in detail. Between 1945 and 2007, 38 serious radiation accidents occurred in nuclear facilities, 26 of them in facilities related to nuclear weapons programmes. Of those 38 accidents, 34 resulted in employee deaths or injury and 7 caused off-site releases of radioactive materials and significant population exposures. Excluding the 1986 accident at Chernobyl (which is discussed in section B below), 29 deaths (including 4 deaths caused by trauma) and 68 cases of radiation-related injuries requiring medical care are known to have occurred as a result of accidents associated with the nuclear fuel cycle.

64. Large radiation sources are in widespread use in industry (industrial irradiation facilities or accelerators) and have been involved in a number of accidents, usually attributable to operator error. All of the 85 accidents covered in the present report involved sufficient levels of exposure to cause radiation-related injuries to workers. Twenty-five deaths and 164 worker injuries were reported in connection with those accidents.

65. Orphan sources are radioactive sources that were originally subject to regulatory control but were then abandoned, lost or stolen. The 29 reported serious accidents involving orphan sources caused radiation-related injuries to the public; altogether, 33 people, including a number of children, died in those accidents. In the accident in Goiânia, Brazil, in 1987, several hundred people were contaminated.

66. In radiation medicine, accidents generally involve errors in the delivery of radiotherapy that are often detected only after many patients have been overexposed. The Committee has reviewed only 29 reported accidents – involving 45 deaths and 613 injuries – since 1967. It is likely that some deaths and many injuries in the medical use of radiation have not been reported. Nevertheless, the reported accidents alone appear to have injured more people than accidents in any other category.

67. Of the accidents that caused exposures of ionizing radiation to the general population, the 1986 Chernobyl accident was by far the most serious one. The collective dose from that accident was many times greater than the combined collective dose from all other accidents causing exposures to the general population.

68. The trends in these accidents vary considerably. Criticality accidents were more common during the early periods of nuclear weapons programmes. Operational events related to the nuclear fuel cycle are sporadic. Accidents in industry and in academic or research establishments appear to have peaked in the late 1970s, falling off to only a few isolated occurrences in industry since 2000. The extensive and worldwide transport of radioactive materials for non-military purposes over the past many years has not resulted in any radiation-related injuries at all. Accidents with orphan sources and those related to medical uses of radiation have shown an increase over recent periods but the data may suffer from underreporting.

(d) Comparison of exposures

69. Although it is clear from the data presented that doses vary substantially by location, group, health-care level and so on, it is nonetheless helpful and customary to summarize the findings on a global basis (see table 1 above). Exposure to natural radiation does not change significantly over time, although individual exposures, particularly to radon, can vary significantly. One of the most striking changes over the past decade or so has been the sharp increase in medical exposures, owing for example to the rapid expansion in the use of computed tomography scanning. In several countries, this has meant that medical exposure has displaced exposure due to natural sources of radiation as the largest overall component. The residual doses from atmospheric testing and from the Chernobyl accident continue to decline slowly. Although occupational exposure shows a low value when averaged across the whole population, the estimated level has increased substantially owing to the recognition of exposure to natural radionuclides in mining. Doses from the nuclear fuel cycle continue to be very small despite the gradual expansion of that sector.

B. Chernobyl accident

70. The 1986 accident at the Chernobyl nuclear power plant in the former Soviet Union was the most severe such accident in the history of civilian nuclear power. Two workers died in the immediate aftermath, and 134 plant staff and emergency personnel suffered acute radiation syndrome, which proved fatal for 28 of them. Several hundred thousand workers were subsequently involved in recovery operations.

71. The accident caused the largest uncontrolled radioactive release into the environment ever recorded for any civilian operation; large quantities of radioactive substances were released into the atmosphere for about 10 days. The radioactive cloud created by the accident dispersed over the entire northern hemisphere and deposited substantial amounts of radioactive material over large areas of the former Soviet Union and other parts of Europe, contaminating land, water and biota and causing particularly serious social and economic disruption to large segments of the population in the countries known today as Belarus, the Russian Federation and Ukraine. Two radionuclides, the short-lived iodine-131 (with a half-life of 8 days) and the long-lived caesium-137 (with a half-life of 30 years), were particularly significant because of the radiation dose they delivered to the public. However, the doses delivered were quite different for the two radionuclides: the thyroid doses from iodine-131 ranged up to several grays within a few weeks after the accident, while the whole-body doses from caesium-137 ranged up to a few hundred millisieverts over the following few years.

72. The contamination of fresh milk with iodine-131 and the lack of prompt countermeasures led to high thyroid doses, particularly among children, in the former Soviet Union. In the longer term, mainly due to radiocaesium, the general population was also exposed to radiation, both externally from radioactive deposits and internally from consuming contaminated foodstuffs. However, the resulting long-term radiation doses were relatively low (the average additional dose over the period 1986-2005 in "contaminated areas"[12] of Belarus, the Russian Federation and Ukraine was 9 mSv, approximately equivalent to that from a medical computed tomography scan), and should not lead to substantial health effects in the general population that could be attributed to radiation. The foregoing notwithstanding, the severe disruption caused by the accident resulted in a major social and economic impact and great distress for the affected populations.

73. Since the accident, the international community has made unprecedented efforts to assess the magnitude and characteristics of its radiation-related health effects. Many initiatives, including those by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA) and the European Commission, were launched to better understand the consequences of the accident and assist in their mitigation. The results of those initiatives were synthesized at an international conference on the theme "One decade after Chernobyl: summing up the consequences of the accident", which was held in Vienna from 8 to 12 April 1996. The conference was co-sponsored by WHO, IAEA and the European Commission in cooperation with the United Nations, the United Nations Scientific Committee on the Effects of Atomic Radiation, the Food and Agriculture Organization of the United Nations, UNESCO and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development. In the international scientific assessments, broadly similar conclusions were reached on the extent and character of the consequences of the accident.

[12] The "contaminated areas" were defined arbitrarily by the former Soviet Union as areas where the soil levels of caesium-137 were greater than 37 kilobecquerels per square metre.

74. The Committee first considered the initial radiological consequences of the accident in its 1988 report.[13] In its 2000 report, the Committee provided a detailed account of the situation as it was known at that time. Subsequent to the publication of that report, eight organizations and bodies of the United Nations system[14] (including the Committee) and the three affected States launched the Chernobyl Forum, which was to generate authoritative consensual statements on the environmental and health consequences attributable to radiation exposure and to provide advice on issues such as environmental remediation, special health-care programmes and research activities. The work of the Chernobyl Forum was appraised at an international conference on the theme "Chernobyl: looking back to go forwards; towards a United Nations consensus on the effects of the accident and the future", which was held in Vienna on 6 and 7 September 2005. At that conference, all the previous assessments of the scale and character of the radiation-related health consequences of the accident were essentially reconfirmed.

75. The objective of the Committee in the present evaluation is to provide an authoritative and definitive review of the health effects observed to date that are attributable to radiation exposure due to the accident and a clarification of the projection of potential effects, taking into account the levels, trends and patterns of radiation dose to the exposed populations. To that end the Committee evaluated relevant information that became available since its 2000 report and ascertained that observations were not inconsistent with assumptions used previously to assess radiological consequences. It also recognized that some outstanding details merited further scrutiny and that its work to provide the scientific basis for a better understanding of the radiation-related health and environmental effects of the accident needed to continue.

76. Although a considerable volume of new research data has become available, the major conclusions regarding the scale and nature of the health consequences of the Chernobyl accident are essentially consistent with the Committee's 1988 and 2000 reports. Those conclusions are as follows:

(a) A total of 134 plant staff and emergency workers received high doses of radiation that resulted in acute radiation syndrome (ARS), many of them also incurring skin injuries due to beta irradiation;

(b) The high radiation doses proved fatal for 28 of those people in the first few months following the accident;

(c) Although 19 ARS survivors had died by 2006, those deaths had different causes that usually were not associated with radiation exposure;

(d) Skin injuries and radiation-related cataracts were among the main sequelae of ARS survivors;

(e) Aside from the emergency workers, several hundred thousand people were involved in recovery operations but, apart from indications of an increase in incidence of leukaemia and of cataracts among those who received higher doses,

---

[13] *Official Records of the General Assembly, Forty-third Session, Supplement No. 45* (A/43/45).

[14] UNEP, Office for the Coordination of Humanitarian Affairs of the Secretariat, the United Nations Development Programme, the United Nations Scientific Committee on the Effects of Atomic Radiation, FAO, WHO, the World Bank and IAEA.

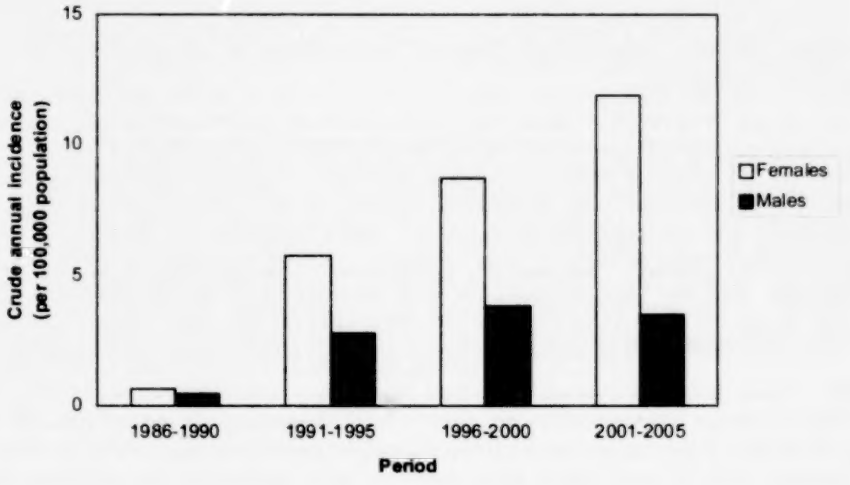
there is to date no consistent evidence of health effects that can be attributed to radiation exposure;

(f) A substantial increase in thyroid cancer incidence among persons exposed to the accident-related radiation as children or adolescents in 1986 has been observed in Belarus, Ukraine and four of the more affected regions of the Russian Federation. For the period 1991-2005, more than 6,000 cases were reported, of which a substantial portion could be attributed to drinking milk in 1986 contaminated with iodine-131. Although thyroid cancer incidence continues to increase for this group (see figure X for the trend in Belarus), up to 2005 only 15 cases had proved fatal;

(g) Among the general public, to date there has been no consistent evidence of any other health effect that can be attributed to radiation exposure.

Figure X

Thyroid cancer incidence among people in Belarus who were children or adolescents at the time of the Chernobyl accident, 1986-1990, 1991-1995, 1996-2000 and 2001-2005



77. Although model-based predictions have been published about possible increases in solid cancer incidence among the general population, for all the population groups considered the doses are relatively small and are comparable to doses resulting from exposure to natural background radiation. The Committee has decided not to use models to project absolute numbers of effects in populations exposed to low doses because of unacceptable uncertainties in the predictions. However, the Committee considers that it is appropriate to continue surveillance.

78. Based on 20 years of studies, it is possible to reconfirm the conclusions of the Committee's 2000 report. Essentially, persons who were exposed as children to radioiodine from the Chernobyl accident and the emergency and recovery operation workers who received high doses of radiation are at increased risk of

radiation-induced effects. Most area residents were exposed to low-level radiation comparable to or a few times higher than the annual natural background radiation levels and need not live in fear of serious health consequences.

79. The Committee considers its most recent evaluation an important point of reference for the United Nations Coordinator of International Cooperation on Chernobyl in responding to the request by the General Assembly pursuant to paragraph 16 of its resolution 62/9 of 20 November 2007, that the Coordinator continue his work in organizing, in collaboration with the Governments of Belarus, the Russian Federation and Ukraine, a further study of the health, environmental and socio-economic consequences of the Chernobyl disaster, consistent with the recommendations of the Chernobyl Forum, and to improve the provision of information to local populations.

C. Effects on non-human biota

80. All species present on the Earth have existed and evolved in environments where they have been exposed to ionizing radiation from the natural background. More recently, however, organisms are also being exposed to artificial sources of radiation, such as global fallout from atmospheric nuclear weapons tests and, in certain locations, controlled discharges of radionuclides or accidental releases of radioactive material.

81. In its 1996 report,[15] the Committee evaluated those doses and dose rates of ionizing radiation below which effects on populations of non-human biota were unlikely. It considered that the individual responses to radiation exposure that were likely to be significant at the population level were in the areas of mortality, fertility, fecundity and the induction of mutations. The Committee also considered that reproductive changes were a more sensitive indicator of radiation effects than mortality, and that mammals were the most sensitive of all animal organisms. On that basis, the Committee derived the dose rates to the most highly exposed individuals that would be unlikely to have significant effects on most populations.

82. Since then, new data on the effects of ionizing radiation have been obtained from follow-up observations of non-human biota in the area around the Chernobyl site. Various organizations have carried out comprehensive reviews of the scientific literature and, in some cases, have developed new approaches for assessing the potential effects on non-human biota. There is a considerable range of end points and corresponding effect levels presented in the literature and also considerable variation in how different researchers evaluate those data. Table 7 provides a brief summary of the relevant data for aggregated categories of organisms.

[15] *Official Records of the General Assembly, Fifty-first Session, Supplement No. 46* (A/51/46).

Table 7
Some effects of ionizing radiation on selected categories of non-human biota

Chronic dose rate (milligrays per hour)	*Category*	*Effect*	*End point*
0.1-1	Plants	Death of pine needles: reduced numbers of herbaceous plants	Mortality, morbidity
	Fish	Reduction in sperm production, delayed spawning	Reproductive damage
About 0.1	Mammals	No detrimental end points described	Morbidity, mortality, reproductive damage

83. The Committee concluded that, overall, there was no evidence to support changing the conclusions of its 1996 report according to which chronic dose rates of less than 0.1 milligrays per hour to the most highly exposed individuals would be unlikely to have significant effects on most terrestrial communities and chronic dose rates of less than 0.4 milligrays per hour to any individual in aquatic populations of organisms would be unlikely to have any detrimental effect at the population level. For acute exposures, studies of the Chernobyl accident experience had confirmed that significant effects on populations of non-human biota were unlikely at doses below about 1 gray.

84. Since the time of the Committee's 1996 report, a great deal of work has been done to investigate and improve data and methods for evaluating pathways through which biota are exposed to radiation in their environment; there have also been many improvements in assessing doses to biota. It is important to note that many opportunities remain for improving current understanding and methods in those areas. An improved understanding of such aspects will improve the overall understanding of the relationship between levels of radiation and radioactivity in the environment and the potential effects on biota.

Appendix I

Members of national delegations attending the fiftieth to fifty-sixth sessions of the United Nations Scientific Committee on the Effects of Atomic Radiation, at which the 2008 scientific report was elaborated

Argentina	A. J. González (Representative), D. Beninson (Representative), P. Gisone (Representative), M. del Rosario Pérez
Australia	P. A. Burns (Representative), S. Solomon, P. Thomas
Belgium	H. Vanmarcke (Representative), H. Bosmans, A. Debauche, H. Engels, J. Lembrechts, J. R. Maisin (Representative), P. Smeesters, J. M. Van Dam, A. Wambersie, H. Bijwaard, R. O. Blaauboer, M. J. Brugmans
Brazil	O. Dias Gonçalves (Representative), J. L. Lipsztein (Representative), M. C. Lourenço, M. Nogueira Martins, D. R. Melo (Representative), E. R. Rochedo
Canada	N. E. Gentner (Representative), R. P. Bradley, K. Bundy, D. B. Chambers, R. M. Chatterjee (Representative), R. J. Cornett, R. Lane, C. Lavoie, S. Vlahovich (Representative), D. Whillans
China	Pan Z. (Representative), He Q., Hou P., Jia J., Li K., Li J., Liu S., Liu Q., Lu J., Pan S., Shang B., Shi J., Su X., Sun J., Sun Q., Wang F., Xiu B., Xuan Y., Yang G., Yang H., Yang X., Yu J., Zhang J., Zhu M.
Egypt	M.A.M. Gomaa (Representative), A. M. el-Naggar (Representative)
France	A. Flüry-Hérard (Representative), E. Ansoborlo, A. Aurengo, D. Averbeck, M. Benderitter, M. Bourguignon, C. Forestier, J. F. Lacronique (Representative), J. Lallemand, J. J. Leguay, C. Luccioni, R. Maximilien, A. Rannou, M. Tirmarche
Germany	W. Weiss (Representative), A. Friedl, P. Jacob, A. Kellerer, J. Kiefer, G. Kirchner, W. Köhnlein, R. Michel, W. U. Müller, C. Streffer (Representative)
India	K. B. Sainis (Representative)
Indonesia	Z. Alatas (Representative), K. Wiharto (Representative)
Japan	O. Niwa (Representative), Y. Yonekura (Representative), T. Asano, M. Doi, Y. Ishikuro, A. Iwama, K. Kodama, H. Kuniyoshi, T. Maeyama, M. Nakano, Y. Nakayama, S. Saigusa, K. Sakai, M. Sasaki, Y. Sasaki (Representative), K. Sato, G. Suzuki, H. Tatsuzaki, S. Yoshinaga, M. Yoshizawa
Mexico	H. Maldonado (Representative)
Peru	L. V. Pinillos Ashton (Representative)

Poland	M. Waligórski (Representative), L. Dobrzyński, M. Janiak, Z. Jaworowski (Representative)
Russian Federation	M. Kiselev (Representative), A. Akleev, R. M. Alexakhin, T. Azizova, N. P. Garnyk, A. K. Guskova (Representative), L. A. Ilyin (Representative), V. K. Ivanov, K. Kotenko, I. I. Kryshev, B. K. Lobach, Y. Mokrov, O. A. Pavlovsky, T. S. Povetnikova, S. Romanov, M. N. Savkin, V. A. Shevchenko, S. Shinkarev
Slovakia	E. Bédi (Representative), P. Gaál, V. Klener, P. Ragan, L. Tomášek, D. Viktory (Representative), I. Zachariášová
Sudan	A. Elgaylani (Representative), K.E.H. Mohamed (Representative)
Sweden	C. M. Larsson (Representative), A. Almén, L. E. Holm (Representative), L. Moberg
United Kingdom of Great Britain and Northern Ireland	R. Cox (Representative), S. Bouffler, R. H. Clarke (Representative), J. Cooper, S. Ebdon-Jackson, G. M. Kendall, T. McMillan, C. Muirhead, R. Paynter, P. Shrimpton, J. W. Stather
United States of America	F. A. Mettler Jr. (Representative), L. R. Anspaugh, B. G. Bennett, J. D. Boice Jr., N. H. Harley, E. V. Holahan Jr., C. B. Meinhold, R. J. Preston, H. Royal, P. B. Selby, A. G. Sowder, A. Upton

Secretary of the United Nations Scientific Committee on the Effects of Atomic Radiation

N. E. Gentner (fiftieth to fifty-second sessions)

M. J. Crick (fifty-third to fifty-sixth sessions)

Appendix II

Scientific staff and consultants cooperating with the United Nations Scientific Committee on the Effects of Atomic Radiation in the preparation of the 2008 scientific report of the Committee

M. Balonov

D. B. Chambers

K. Faulkner

G. Howe

G. Ibbott

G. Kirchner

D. Melo

R. Ricks

E. Rochedo

M. Stabin

G.A.M. Webb

D. Woodhead